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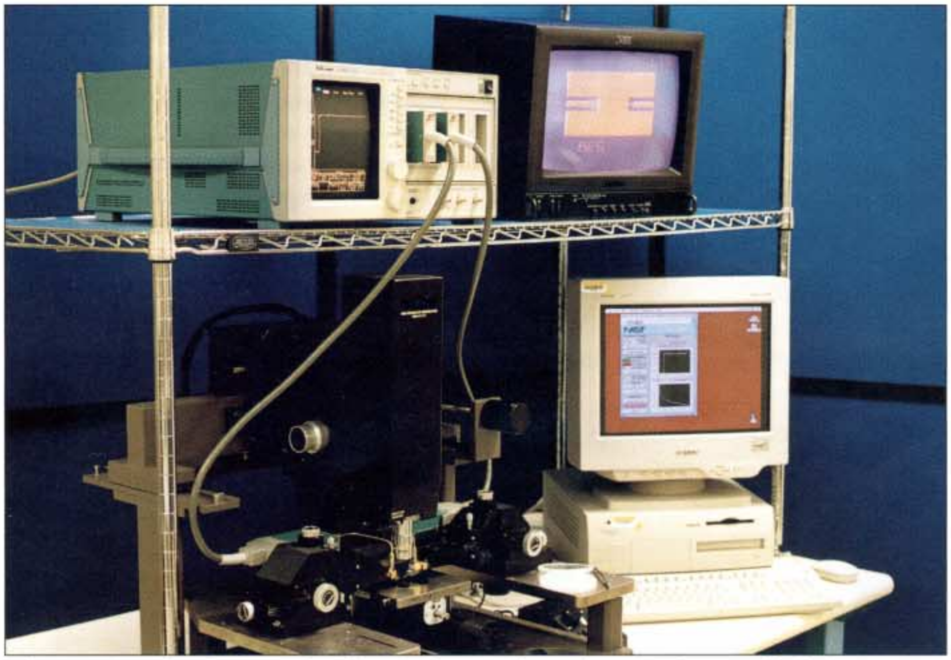
Taking RF and Microwave Device Measurements With a Digital Sampling Oscilloscope



The NIST time-domain network analyzer is shown with a probe station for on-wafer device measurements.

by Donald DeGroot and Jeffrey Jargon, National Institute of Standards and Technology

The Challenge: Characterizing RF and microwave devices using time-domain instrumentation.
The Solution: Creating a virtual time-domain network analyzer in LabVIEW™ that acquires waveforms from an oscilloscope over GPIB and calibrates the data with routines called from code interface nodes.

Researchers at the National Institute of Standards and Technology (NIST) in Boulder, Colorado developed a virtual instrument (VI) using National Instruments LabVIEW software to acquire broadband S-parameters (vector transmission and reflection coefficients) using a digital sampling oscilloscope with time-domain reflection/transmission (TDR/T) capabilities. Though this software and its associated methods were developed for internal research, NIST now offers TDNACal as a stand-alone application to all engineers and researchers interested in using a conventional time-domain instrument for accurate radio-frequency and microwave device characterization.

Measurement Needs

TDNACal is a product of an ongoing project at NIST to characterize microelectronic transmission lines, interconnections, and packaging using time-domain instrumentation. Because earlier network analyzer measurements clearly showed that transmission line parameters depend strongly on frequency, particularly for those structures encountered at the chip level, the current project called for a method of acquiring frequency-dependent data using an oscilloscope. The team of researchers turned to time-domain network analysis (TDNA) to accomplish this.

The NIST team needed to create a new system to perform the appropriate fast Fourier transform (FFT) and frequency-domain calibration. LabVIEW and the virtual instrument concept supplied the solution for creating a time-domain network analyzer. It provided a new instrument with frequency-domain functionality by using a physical time-domain instrument solely for waveform acquisition.

Through the creation of a virtual time-domain network analyzer using LabVIEW, NIST researchers have provided the means of controlling an oscilloscope over GPIB to make accurate frequency-dependent device measurements in the RF and microwave ranges.

Virtual Instrument Design

In developing TDNACal, the group decided on four guiding criteria: 1. A single version of the source code, but multiple executable versions for different computer platforms; 2. Portable calibration algorithms written in C; 3. Modularity for ease of maintenance and expansion; and 4. A friendly and informative user interface. These criteria were met in developing the VI as a three-tier hierarchy while maintaining separation between instrument control, file I/O, FFT, calibration, and data display.

continued on page T-2

Taking RF and Microwave Device Measurements With a Digital Sampling Oscilloscope

continued from T-1

Results

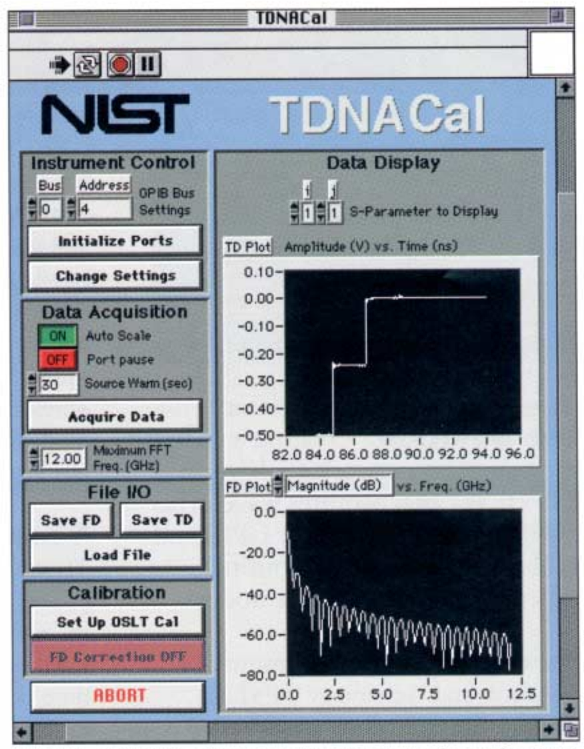
By applying modular programming, code interface nodes, and the Application Builder, the researchers produced a single maintainable version of the source code while compiling run-time versions of TDNACal in different computer systems. The front panel of the resulting virtual instrument is shown in this figure. Like the source code, the control blocks are separated by functions.

The researchers verified the operation and repeatability of TDNACal through extensive measurements and comparisons. Most of this work was performed with on-wafer characterization of transmission lines (nominal $Z_o \approx 50\mu$), short circuits, and resistors using the probe stations system. However, the team verified the bench-top operation through the measurement of coaxial Beatty standards. The team compared the results of calibrated TDNA measurements of a wafer-level interconnect to calibrated measurements of the same device made with a commercial vector network analyzer. The TDNACal data for this example transmission line agree remarkably well with the vector network analyzer results up to 12 GHz.

Summary

Through the creation of a virtual time-domain network analyzer using LabVIEW, NIST researchers have provided the means of controlling an oscilloscope over GPIB to make accurate, frequency-dependent device measurements in the rf and microwave ranges. They have successfully applied TDNACal to electronic interconnect and packaging characterizations; it is suitable for a variety of linear device and system measurements as well.

For further information or to obtain a free copy of TDNACal, contact Don DeGroot, NIST, Mail Code 813.06, 325 Broadway, Boulder, CO 80303-3328, tel (303) 497-7212, fax (303) 497-3970, e-mail degroot @boulder.nist.gov



With the TDNACal front panel, users can configure the scope, acquire and calibrate the frequency-domain data, view the results, then save the data to files.